Conducting Research with Junior and High School Students Using a Remotely Operated Vehicle—A Collaborative Project Between Private and Public Agencies

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Abstract
A partnership between staff from the Port Townsend Marine Science Center (PTMSC), the University of Washington Friday Harbor Laboratories (FHL), Western Washington University Shannon Point Marine Center (SPMC) and Washington Department of Fish and Wildlife (WDFW) was formed to utilize existing underwater technologies to expose junior high and high school students to the marine sciences. Scientists from PTMSC, FHL, SPMC and WDFW, in collaboration with science teachers from local school districts, developed a pilot project that would allow students to collect and analyze a variety of biological and geological data with a small remotely operated vehicle (ROV) owned by FHL. Grant moneys obtained from a prominent local company were used to establish study sites at two rocky reef locations in San Juan County, Washington and to charter a research vessel equipped to handle the ROV. The sampling regime was designed such that data collected by the students could be used to augment reef-fish data being collected by scientists at academic and governmental institutions.

Providing middle and high school students with advanced underwater technology (i.e. ROV's) for student research is a highly innovative approach to engaging students in field science investigations. In this paper we describe the processes of project development and initiation so that they might be used as a template for the development of similar programs around the country.

Introduction

Background
Today's high-tech world of documentary television, computers and the Internet exposes pre-college students to a vast array of scientific technology, including many of the tools used by marine scientists in their quest for knowledge and understanding of the underwater realm. Unfortunately, given the expense and limited availability of many of these technologies, students seldom have the opportunity to use the technology in a "hands-on" setting and are instead forced mainly into the role of observers.

Teachers have often commented that students have a higher motivation for learning when they are allowed to use real equipment and apply it to real-life situations. This is especially true for today's high-tech tools that can offer students new ways of visualizing their world. Based on this premise, a partnership was formed between several public and private agencies in Washington State to create a pilot project that would expose pre-college students to the marine sciences by allowing them to use a remotely-operated vehicle (ROV) and other scientific equipment to collect data that they would analyze themselves, under the direction of participating scientists.

Sponsoring Organization and Project Partners
The Port Townsend Marine Science Center (PTMSC, http://www.ptmsc.org/), located at Fort Worden State Park in Port Townsend, Washington, was the lead entity for the project. The PTMSC is a non-profit organization founded in 1982 to promote understanding of the marine and aquatic sciences. The center provides a number of activities for teachers, students, and the general public, including hands-on exhibits, teacher workshops, summer camps, school programs, and natural history and research cruises. The PTMSC is also linked to the Puget Sound Action Team (PSAT) via webcam that transmits underwater images that are displayed at the PSAT website (www.wa.gov/puget_sound/About_Sound/webcam.htm).

Marine scientists from the University of Washington Friday Harbor Laboratories (FHL), Western Washington University Shannon Point Marine Center (SPMC) and the Washington Department of Fish and Wildlife (WDFW) partnered with PTSMC staff to provide equipment, scientific expertise, and logistical support to the project. PTSMC staff consulted with FHL, SPMC, and WDFW scientists on a range of topics, including project feasibility, study site location, survey design, historical data, data analysis, and equipment.

Committed and creative teachers were essential to making this project a success. It was important to identify teachers who were not only willing to arrange for their students to take part in working with the ROV, but were also prepared to invest considerable time in developing interesting ways of using the experience of working with the ROV to enrich their classroom curriculum. We also hoped they would find ways to share the experience with students who were unable to participate directly in the project, as well as with their families and local communities.

There are many outstanding marine science teachers throughout the Puget Sound area, any of whom would have made an excellent contribution to this project, but practicality dictated that the field be limited to teachers working somewhat close to the San Juan Islands where the ROV was located. At the same time, it was thought that including teachers from different school districts and representing different teaching specialties might help generate more ideas and lead to interesting possibilities for exchanges between teachers and students.

Two science teachers from the Anacortes School District became the nucleus of the program. The educational staff of the SPMC recommended several other local area teachers who had received training at that facility. One was a beginning teacher in the Friday Harbor School District and another was a physics teacher for the Oak Harbor School District. A highly motivated biology teacher working with at-risk students in the Chimacum School District and well known at the PTMSC, was also invited to participate. Finally, a physical science teacher from the Stanwood School District who had taken part in the UW Department of Oceanography's REVEL program (http://www.ocean.washington.edu/outreach/revel/) participated in the project until family health issues forced her to withdraw in March 2003.

Once the initial group was formed and funding obtained, the representative school districts were informed of the participation of their teachers and students. In no case was any objection raised by a school district administration to allowing their teachers and students to participate in the program.

Project Objectives

The initial objective of the project was to develop a pilot program that would explore the utility of using a remotely-operated vehicle (ROV) to enhance science teaching in secondary school classrooms. A secondary objective of the project was to determine whether research conducted by the students could be useful to marine scientists from a variety of public and private agencies, including FHL, SPMSC, WDFW, and the Washington Department of Natural Resources (DNR). By careful selection of the study site and through consistent survey methodology, it may be possible to provide scientists with a long-term data set that could be used to augment current and historical data series.

Through the course of the project, project participants also hoped to improve student awareness of Puget Sound marine environments and to increase student understanding of how marine research is being conducted in the Puget Sound region. The project was also designed to provide challenging and motivating experiences for pre-college students, as well as to create opportunities for students to develop critical-thinking and creative problem-solving skills in a "real-world" environment.

Funding

Early in the planning stages of the project, one of the participating teachers suggested that the Shell Puget Sound Refinery, based in Anacortes, might be willing to fund the first year of the program. Subsequently, a formal proposal was developed and presented to the refinery staff, and in June 2002, funding for the pilot project, officially titled **Pre-College Marine Research Program with Remotely Operated Vehicle**, was approved and a $40,000 grant issued to the PTMSC. Activities supported by the funds included:

1. A one-day ROV practice cruise for the participating teachers.
2. Five ROV research cruises with the students.
3. Stipends for participating teachers for equipment, travel, and teaching.
4. Coordination and grant writing for future funding.

Expenses incurred by project participants other than the selected teachers were covered by the participant's parent organization or "out-of-pocket" by individual participants.

Project Implementation

Project planning began in October 2001 with a series of meetings between teachers and academic and agency scientists that focused on goal-setting, survey design, and logistics planning. Upon receiving the grant from the Shell Puget Sound Refinery in June 2002, the teachers were able to purchase equipment and other materials to support the project in their classrooms.

In May of 2002, a one-day ROV deployment exercise was conducted near Anacortes, Washington with the six participating teachers in order to familiarize them with the equipment operation and logistics planning. This exercise generated another round of meetings to finalize the study site selection and refine the ROV survey methods.

Finally, in October 2002, the first round of student ROV deployment exercises was undertaken. On back-to-back days, students from the Chimacum and Anacortes School districts each participated in a one-day deployment of the ROV where the students worked alongside scientists, navigating the ROV and collecting data at the selected study site. The second round of student ROV deployments is scheduled for May 2003 with the remaining two school districts.

Site Selection

The site selection process involved a number of conversations among all parties. With the concerns of the project administrators in mind, the scientific advisors from the University of Washington and WDFW used a number of factors to select potential survey sites, including vessel and personnel safety, weather and tidal conditions, and proximity to the UW Friday Harbor Labs.

Since one of the primary goals of the project was to provide useful information to academic and government scientists, our initial plans were to establish two survey sites, one inside an existing marine protected area (MPA) and the second in similar habitat outside of any existing MPA. Because WDFW scientists have been studying populations of rockfish and lingcod in the San Juan Islands for over a decade, considerable attention was given to locating a site that contained habitat preferred by these species. Current and tidal conditions played a major role in where the site was eventually located. Many of the preferred sites being studied by WDFW scientists are located in high current areas with short periods of slack tidal flow that would severely limit the number of students allowed to pilot the ROV. Consequently, most of these locations were removed from consideration, thereby reducing the number of potential survey sites to a handful of likely locations.

In order to maintain a high level of student interest and to provide increased participation and a wider range of potential study projects for the students, our goal was to select a site that contained a variety of habitat types with potentially high species diversity. While we had originally hoped to select an MPA site and matching unprotected site, logistical constraints resulted in the selection of a single site within an existing MPA established by the University of Washington in the early 1990s. This site, approximately 1/2 nautical mile southwest of Point George on the south side of Shaw Island (Figure 1), offered a range of habitat types ranging from bedrock and boulder fields along the shoreline, transitioning to a mix of cobble and gravel and then to sand as depth increased. The range of habitats at this site also provided a diversity of fish, invertebrates, and algal species for the students to study. The selected site afforded good protection from the prevailing weather patterns, was in close proximity to the UW Friday Harbor Labs where the ROV is based, and was not exposed to the extreme tidal currents experienced at several of the other potential survey locations.

Equipment and Support Vessels

The focal piece of the project was a Deep Ocean Engineering® Phantom HD-2 remotely operated vehicle (ROV) owned by the University of Washington Friday Harbor Laboratories. The FHL's Phantom ROV is equipped with a high-definition color video camera capable of capturing high-resolution images under low-light conditions, and was fitted with a laser-scaling device for measuring organisms or other objects of interest. The vehicle utilizes two horizontally mounted thrusters to provide forward and reverse thrust and to turn the vehicle left and right. A vertically mounted thruster allows the vehicle to be maneuvered up and down, while a horizontal thruster mounted perpendicularly to the forward/reverse thrusters provides left and right lateral thrust capability. The ROV is connected to the surface control unit via a PVC jacketed neutrally buoyant umbilical cable that supplies the electrical needs of the vehicle and transmits the video images to the operator. The control box consists of a pair of joysticks used to drive the ROV, and controls for the camera, lights and thruster speed functions.

To track the location of the ROV on the bottom, an Accusonics® TrackPoint II Ultra-short Acoustic Baseline System was installed on the support vessel. The ROV was fitted with an acoustic transponder that relays a signal to the TrackPoint

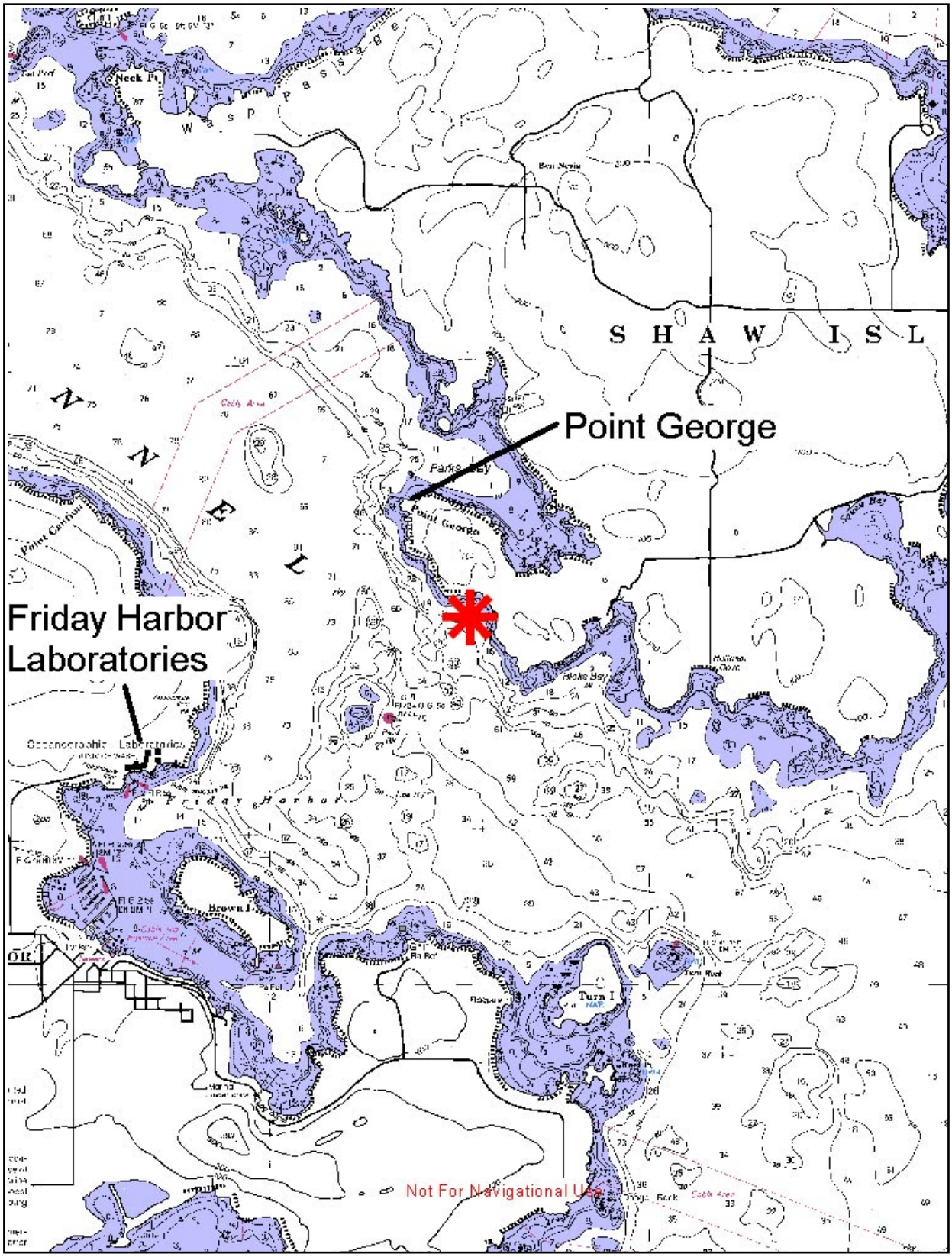

Figure 1. Study site location on Shaw Island (black star) used for first round of student ROV deployments in October 2002.

hydrophone attached to the support vessel and interfaced to a laptop computer running Hypack Max navigation software. The positions of both the survey vessel and the ROV could then be plotted in real-time directly to the laptop screen to allow the operator to know exactly where the ROV was at all times.

Other sampling equipment used during the ROV excursions included Secchi-disks, dissolved oxygen meters, plankton nets, Niskin bottles, and bottom-grabs for sediment sampling. Most of this equipment was provided by FHL or by participating school districts.

The survey vessel used for the teacher deployment exercise and the first two student deployments was the 43' *R/V Mary Beth*, owned by Marine Resource Consultants and operated by Dr. Jim Norris of Port Townsend, WA. In February 2003, the University of Washington Friday Harbor Laboratories acquired a 56-foot converted purse seiner, the *R/V Centennial*, which will be used for all future student ROV deployment exercises.

ROV Transect Line and Survey Method

Since one of the project goals was to provide the opportunity for all of the students to pilot the ROV, we required a survey method that would meet this goal while still allowing the collection of meaningful data. Several options were considered, but it was eventually decided that the use of a fixed line along the bottom would be the easiest way for students to drive the ROV without getting disoriented while providing that the same transect was being surveyed consistently over time. This method has been employed in numerous SCUBA diving surveys over the past 30 years and appeared easily applicable to an ROV survey. For this project, we used a 3/8-inch diameter flexible braided lead-core line (i.e., leadline), anchored above the high-tide line and laid out along the bottom obliquely from the shoreline extending to a depth of about 100' mean lower low water (mllw), with a total overall transect length of 150 m.

Shipboard Activities

The first round of student ROV deployment exercises was undertaken in October 2002. On back-to-back days, the Chimacum and Anacortes School districts each participated in a one-day deployment of the ROV where the students collected data at the selected study site. The first day was highlighted by several logistical problems in operating the ROV and managing the activities of the 18 students aboard the vessel. However, by the second day, these issues had been resolved and the work proceeded in a much smoother manner.

On the days of the of the deployment exercises, the support vessel picked up the students at the ferry landings on Orcas and San Juan Islands, respectively, and transited to the study site. Once on site and with the vessel securely anchored, the ROV was deployed and driven to the bottom by one of the science advisors. After locating the deep end of the transect line, the ROV was piloted along the leadline to where the thickest portion of the kelp bed prevented any further travel which was approximately 10 m mllw. The ROV was then turned around and driven back to the deep end of the transect line. Under the direction of a science advisor, each student was then allowed to pilot the ROV along at least one length of the leadline, and all transects were recorded on digital videotape (Mini-DV format) for later analysis by the students. The video image was also displayed on a 43" plasma screen television, enabling the students in the cabin to watch and record animals seen on the live video image. One student was assigned to narrate the recording with data, which proved useful when reviewing the video back in the classrooms. After all of the students had piloted at least one ROV transect and rotated through each of the stations on board the ship (see below), one of the science advisors piloted the ROV off-transect to explore other areas and to collect additional information for the students.

When not engaged with piloting the ROV or recording "real-time" data from the live video image, the remaining students were busy participating in a number of other shipboard activities. Several science stations were set up around the vessel through which the students rotated during the course of the day. These included stations for plankton sampling with a vertically retrieved net, sampling water quality and light penetration, and collecting bottom sediments. One additional station was the cable coiling station, where students learned how to deploy and retrieve the ROV umbilical cable. All of these activities were documented on digital videotape by a teacher or designated student for future project planning presentation to the funding source.

In addition to the activities listed above, each student group had come on board with specific investigations planned in advance. One teacher had her students interview the scientific advisors about ROV technology and survey methods, and investigate the technology used to track the ROV underwater. Another class brought equipment for sampling bottom sediments and water clarity, and they worked very hard sampling at depths and in current conditions beyond what they had expected at the study site.

Student Follow-up Activities
As previously described, initial plans were to collect data from two transects with each group of students, one located inside a marine reserve and one located in a comparable habitat outside the reserve. The students' follow-up activities would then center on making comparisons between the data recorded at the two locations. However, because the first round of deployments did not include a control transect outside of the reserve site, student follow-up activities necessarily focused on other areas. One teacher had his students build small, fully operational ROVs from PVC pike and small submersible motors. Other teachers had their students produce an informational videotape and PowerPoint presentations on the marine life encountered with the ROV. At least one teacher developed a full year of activities around the single ROV deployment event. At the end of the current school year, the participating teachers and students will share projects with one another and with the larger community through public displays and a public presentation coinciding with the annual Waterfront Festival in Anacortes, Washington.

Conclusions

What We've Learned
First and foremost, we learned that coordinating the activities of 18 to 20 pre-college students on board a vessel around local weather and tidal conditions can be a challenging, but rewarding, experience for everyone. Of paramount importance is keeping the students occupied while on board the vessel in order to reduce background noise and to increase participation in the individual activities. Fortunately, the selected students were highly motivated and excited to be participating in the project, making this task relatively easy for the teachers and shipboard personnel.

We also learned that the majority of students are not intimidated by the ROV and it's associated technology. Unbound by the constraints of "traditional" scientific methodology, the students were free to ask questions and make "mistakes,"which promotes faster learning and creative thinking. Unfortunately, because the students were only allowed one day for their exercise and most had only one opportunity to drive the ROV, they came away with as many questions as answers. Nonetheless, it was truly rewarding to experience the unbridled enthusiasm of the students as they saw fish and other organisms reacting to the ROV as it was driven along the transect.

Conducting meaningful research with an ROV and pre-college students appears to be an attainable goal. Due to logistical constraints during the project's first year, we were not able to conduct sampling at both an MPA and non-MPA site, however, the acquisition of the R/V Centennial may allow us to achieve this goal in the second round of student deployment exercises to be conducted in the spring of 2003.

Current Status and Future Plans
Students that participated in the first round of deployment exercises should be completing their individual projects by May 2003, while students from the remaining school districts are planning for their upcoming deployments. The participating teachers are enthusiastic about continuing the project and are discussing how the project might be continued during the next school year.

In the summer of 2003, all parties will meet to evaluate the outcomes and challenges experienced during the first year of the project. Discussions will include future funding sources, the possibility of expanding the program to include one or two more teachers, and whether or not to pursue a cross-culture or cross-country partnership to enhance the learning experience for the students.

In May 2003, some of the results from the first two deployment exercises will be presented to the public at the Anacortes Festival. Several of the participating students and teachers will be on hand to interpret the displays and publicize the project. Throughout the project, the local media has been informed of project activities and several articles have appeared in local newspapers.